United States Department of Agriculture
Animal and Plant Health Inspection Service
Plant Protection and Quarantine

Importation of Fresh Potato (*Solanum tuberosum* L.) Tubers for Consumption from Mexico into the Continental United States

A Pathway-initiated Risk Assessment

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Executive Summary

This risk assessment documents the risks associated with the importation, from Mexico into the continental United States, of potatoes, *Solanum tuberosum* L., intended for consumption. Information on organisms associated with potatoes in Mexico revealed that pests of quarantine significance exist. Without mitigation, these pests could be introduced into the United States via the importation of commercially produced potatoes. Pests of quarantine significance include the insect *Epicaerus cognatus* Sharp (Coleoptera: Curculionidae) and the following pathogens: the bacterium *Ralstonia solanacearum* race 3 (Smith) Yabuuchi *et al*. (Burkholderiales); two pathogenic fungi, *Angiosorus solani* Thirum. & O'Brien (Basidiomycota: Ustilaginales) and *Rosellinia bunodes* (Berk. & Broome) Sacc. (Ascomycota: Xylariales); and three plant parasitic nematodes, *Globodera pallida* (Stone) Behrens (Heteroderidae), *G. rostochiensis* (Wollen.) Behrens, and *Nacobbus aberrans* Thorne & Allen (Pratylenchidae).

A *Consequences of Introduction* value was estimated by assessing five elements that reflect the biology and ecology of the pests: climate/host interaction, host range, dispersal potential, economic impact, and environmental impact. A *Likelihood of Introduction* value was estimated by considering both the quantity of the commodity imported annually and the potential for pest introduction and establishment. The two values were summed to estimate an overall *Pest Risk Potential*, which is an estimation of risk in the absence of mitigation. All of the pathogens were given a Pest Risk Potential value of High. The insect pest was estimated to pose a medium risk. These pests pose unacceptable phytosanitary risks to U.S. agriculture. Visual inspection at ports-of-entry is insufficient to safeguard U.S. agriculture from these pests. Additional, phytosanitary measures are considered necessary to reduce pest risk.

Following are some mitigative measures that may be considered within a systems approach to reduce the possible risks associated with the above-mentioned quarantine pests:

- Potato production within pest free areas;
- Imports limited to potatoes for consumption;
- Use of certified seed potatoes;
- Chemical spray program in the field;
- Program oversight by U.S. officials;
- Application of sprout inhibitor;
- Field and phytosanitary inspection, sampling, and testing procedures prior to planting and during the production season;
- Use of pest resistant varieties of potato;
- Shipments traceable to place of origin;
- Point-of-entry sampling and inspection;
- Limits on distribution and intended use

This document identifies and evaluates risks and discusses known risk mitigations. It does not seek to recommend specific measures or a particular systems approach as would be outlined in a formal workplan, nor does it attempt to assess the adequacy of a particular measure or systems approach in reducing risk.

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A. Introduction

This risk assessment was prepared by the Plant Epidemiology and Risk Analysis Laboratory (PERAL) of the United States Department of Agriculture, Animal and Plant Health Inspection Service, Plant Protection and Quarantine, Center for Plant Health Science and Technology (USDA, APHIS, PPQ, CPHST) to examine the plant pest risks associated with the importation, from Mexico into the continental United States, of commercially produced potato, S*olanum tuberosum* L. (Solanaceae), tubers intended for consumption. Estimates of risk are expressed in terms of high, medium, or low. The risk assessment is "pathway-initiated" in that it is based on the potential pest risks associated with the commodity as it enters the United States.

Regional and international plant protection organizations, such as the North American Plant Protection Organization (NAPPO) and the International Plant Protection Convention (IPPC) administered by the Food and Agriculture Organization (FAO) of the United Nations, provide guidance for conducting pest risk assessments (FAO, 1995, 1996a, 2001a). The methods used to initiate, conduct and report this assessment are consistent with the guidelines provided by the IPPC and NAPPO. The use of biological and phytosanitary terms conforms with the Definitions and Abbreviations (Introduction Section) in International Standards for Phytosanitary Measures, Section 1-Import Regulations: Guidelines for Pest Risk Analysis (FAO, 1996a), and the Glossary of Phytosanitary Terms (FAO, 2001b). These guidelines describe three stages of pest risk analysis: Stage 1 (initiation), Stage 2 (risk assessment), and Stage 3 (risk management). This document is consistent with these guidelines and applicable U.S. regulations (7 CFR §319.40-11).

FAO (1996a) defines *pest risk assessment* as "Determination of whether a pest is a quarantine pest and evaluation of its introduction potential." *Quarantine pest* is defined as "A pest of potential economic importance to the area endangered thereby and not yet present there, or present but not widely distributed and being officially controlled." Thus, pest risk assessments should consider both the consequences and likelihood of introduction of quarantine pests. Both issues are addressed in this document.

Production of potatoes in Mexico

Only elements of the production system in Mexico that are relevant to this risk assessment are outlined here. Currently, production of potatoes for consumption occurs in two areas in Mexico (Fig. 1). The first area is in the Central region and generally has lower yields from fields that rely on rainfall during the spring-to-summer production cycle (CIP, 2002). The second area includes states of the north and some states of the region known as the "Bajio." The majority of potatoes from these areas are white-skinned varieties, and are produced in irrigated fields during the dry season, so yield (t/ha) can be twice that of the Central region. Producers in this region are classified as "agricultural entrepreneurs," and generally use highly mechanized cultivation practices (CIP, 2002).

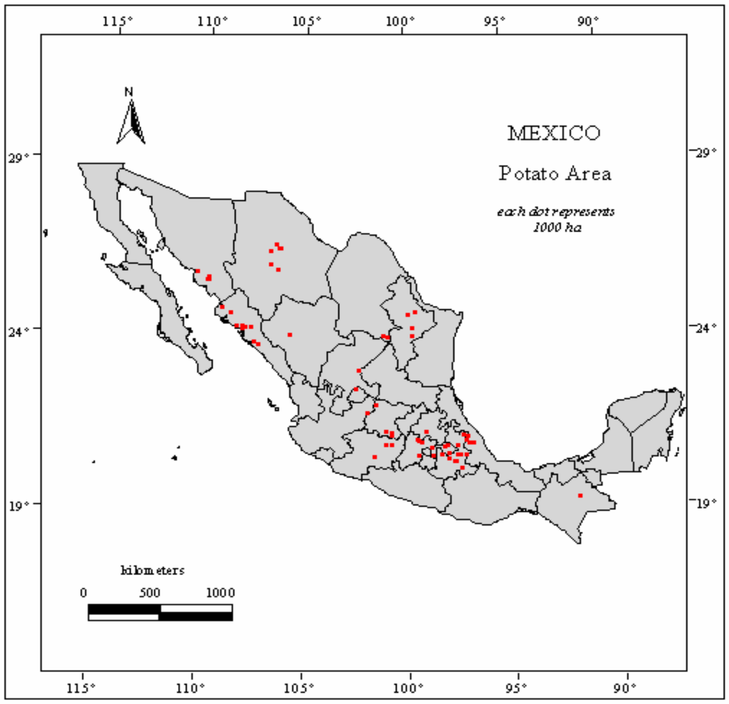

Figure 1. Potato production areas in Mexico (CIP 2002).

B. Risk Assessment

1. Initiating Event: Proposed Action

This commodity-based, pathway-initiated pest risk assessment examines the potential phytosanitary risks associated with the importation into the continental United States of potato tubers from Mexico. The importation of fruits and vegetables into the United States is regulated under 7 CFR §319.56. The Mexican government specifically requested APHIS to consider changing its regulations to allow market access to Mexican table stock potatoes. APHIS evaluation of this request is consistent with its mission under the Plant Protection Act of 2000 (7 U.S.C. §§7701-7772).

2. Assessment of the Weed Potential of Potato

If the species considered for import poses risks as a weed pest, then a "pest initiated" risk assessment is conducted. The results of the weed potential screening for potato did not prompt a pest initiated risk assessment because potatoes are present in the United States and are not reported as weeds (Table 1).

Table 1. Assessment of the Weed Potential of Potato

Commodity: Potato (*Solanum tuberosum*) (Solanaceae)

Phase 1: In the United States, potatoes are grown commercially in 35 states.
Phase 2: Is the species listed in:

- No — *Geographical Atlas of World Weeds* (Holm *et al*., 1979)
- No — *World's Worst Weeds* (Holm *et al*., 1977) or *World Weeds: Natural Histories and Distribution* (Holm *et al*., 1997)
- No — Report of the Technical Committee to Evaluate Noxious Weeds; Exotic Weeds for Federal Noxious Weed Act (Gunn and Ritchie, 1982)
- No — *Economically Important Foreign Weeds* (Reed, 1977)
- No — Weed Science Society of America list (WSSA, 1989)
- No — Is there any literature reference indicating weediness, *e.g*., AGRICOLA, CAB Abstracts, Biological Abstracts, AGRIS; search on “potato” combined with “weed.”

Phase 3: Potato is not listed as a common weed in the above references.

3. Previous Risk Assessments, Current Status and Pest Interceptions

Decision History for Potato from Mexico

There is one previous pest risk assessment of potato propagating material entering the United States from Mexico, and a decision exists regarding potato from Nicaragua, which includes consideration of some of the same pests (PPQ, 2002).

Pest interceptions on potato from Mexico are summarized in Table 2. Currently, potato imports from Mexico are not authorized by 7 CFR §319.56.

Table 2. PPQ Interceptions on potato (*Solanum tuberosum*) from Mexico (1985-2002).[1]

Organism	Plant Part Infested	Location of Interception	Purpose	Number of Interceptions
INSECTA				
COLEOPTERA				
Chrysomelidae				
Chrysomelidae, species of	Stem	Baggage	Consumption	1
Epitrix sp.	Stem	Baggage	Consumption	1
Curculionidae				
Colecerus sp.	Stem	Baggage	Consumption	1
Conotrachelus sp.	Stem	Baggage	Consumption	2
Copturus sp.	Root	Baggage	Consumption	2
Curculionidae, species of	Root	Baggage	Consumption	1
Curculionidae, species of	Root	General cargo	Consumption	1
Curculionidae, species of	Root	Miscellaneous	Non-entry	1
Curculionidae, species of	Stem	Baggage	Consumption	5
Cylindrocopturus sp.	Root	Baggage	Consumption	1

Organism	Plant Part Infested	Location of Interception	Purpose	Number of Interceptions
Diaprepes sp.	Root	Baggage	Non-entry	1
Epicaerus cognatus Sharp	Root	Baggage	Consumption	1
Epicaerus sp.	Bulb (?)	Baggage	Consumption	2
Epicaerus sp.	Root	Baggage	Consumption	18
Epicaerus sp.	Root	Quarters	Non-entry	1
Epicaerus sp.	Stem	Baggage	Consumption	34
Epicaerus sp.	?	Baggage	Consumption	3
Premnotrypes sp.	Root	Baggage	Consumption	1
Rhynchophorinae, species of	?	Baggage	Consumption	1
Sphenophorus sp.	Root	Baggage	Consumption	1
Trichobaris sp.	Stem	Baggage	Consumption	1
Elateridae				
Conoderus laurenti (Guerin)	Stem	Baggage	Consumption	1
Scarabaeidae				
Diplotaxis sp.	Root	Baggage	Consumption	1
Tenebrionidae				
Blapstinus sp.	Root	Baggage	Consumption	1
Epitragus sp.	Stem	Baggage	Consumption	2
DIPTERA				
Agromyzidae, species of	Leaf	Permit cargo	Consumption	1
Tephritidae, species of	Root	Baggage	Consumption	1
HETEROPTERA				
Lygaeidae				
Prytanes sp.	Root	Baggage	Consumption	1
Pentatomidae				
Euschistus sp.	Root	Baggage	Consumption	1
HOMOPTERA				
Pseudococcidae				
Planococcus sp.	Fruit	Baggage	Consumption	1
LEPIDOPTERA				
Lepidoptera, species of	Root	Baggage	Consumption	1
Gelechiidae, species of	Root	Baggage	Consumption	5
Gelechiidae, species of	Root	Stores.	Non-entry	1
Gelechiidae, species of	Stem	Baggage	Consumption	1
Noctuidae, species of	Fruit	Baggage	Consumption	1
Oecophoridae, species of	Stem	Baggage	Consumption	1
Sesiidae, species of	Stem	Baggage	Consumption	1

Organism	Plant Part Infested	Location of Interception	Purpose	Number of Interceptions
FUNGI				
Angiosorus solani Thirum. & O'Brien	Stem	Baggage	Consumption	4
Angiosorus solani Thirum. & O'Brien	?	Baggage	Consumption	1
Cladosporium sp.	Root	Baggage	Consumption	3
Cladosporium sp.	Stem	Baggage	Consumption	2
Coniothyrium sp.	Root	Baggage	Consumption	1
Fusarium sp.	Root	Baggage	Consumption	1
Fusarium sp.	Stem	Baggage	Consumption	1
Microsphaeropsis sp.	Stem	Baggage	Consumption	1
Phoma sp.	?	Baggage	Consumption	1

[1]Records from the PPQ Port Information Network (PIN 309) database.

4. Pest Categorization—Identification of Quarantine Pests and Quarantine Pests Likely to Follow the Pathway

Pests associated with potato that also occur in Mexico are listed in Table 3. This table also notes the presence or absence of these pests in the United States, the affected plant part(s), the quarantine status, an indication of the pest-host association, and pertinent citations for pest biology and distribution. Details of pest biology or distribution were the reason that several organisms were eliminated from consideration as sources of phytosanitary risk on potato, *i.e.*, they do not satisfy the definition of a quarantine pest (FAO, 2001b) or are unlikely to remain with the tubers during the harvesting and packing processes.

Table 3. Pests in Mexico Associated with Potato (*Solanum tuberosum*).

Pest	Geographic Distribution[1]	Plant Part Affected	Quarantine Pest	Likely to Follow Pathway	References
ARTHROPODA					
ACARI					
Acaridae					
Rhizoglyphus robini (Claparède)	MX, US	Tuber	No	Yes	Lopez and Gonzalez, 1999
Eriophyidae					
Aculops lycopersici (Tryon)	MX, US	Vegetative	No	No	CPC, 2001; Metcalf and Metcalf, 1993
Tetranychidae					
Tetranychus cinnabarinus (Boisduval)	MX, US	Vegetative	No	No	Bolland *et al.*, 1998; CPC, 2001
Tetranychus marianae McGregor	MX, US	Vegetative	No	No	Bolland *et al.*, 1998; CPC, 2001; Denmark, 1970

Pest	Geographic Distribution[1]	Plant Part Affected	Quarantine Pest	Likely to Follow Pathway	References
COLEOPTERA					
Anthribidae					
Araecerus fasciculatus (De Geer)	MX, US	Flowering/ fruiting; post-harvest	No	Yes	Chittenden, 1896; CPC, 2001
Chrysomelidae					
Acalymma trivittatum (Mannerheim)	MX, US	Vegetative, roots	No	No	MacGregor and Gutierrez, 1983; Metcalf and Metcalf, 1993
Diabrotica balteata LeConte	MX, US	Vegetative, roots	No	No	CPC, 2001; Krysan, 1986; MacGregor and Gutierrez, 1983; Metcalf and Metcalf, 1993
Diabrotica undecimpunctata howardi Barber	MX, US	Vegetative	No	No	MacGregor and Gutierrez, 1983; Metcalf and Metcalf, 1993
Epitrix sp.	MX	Stem	Yes[2]	No	PPQ interception
Epitrix cucumeris (Harris)	MX, US	Vegetative, roots	No	No	Gutierrez, 1983; Metcalf and Metcalf, 1993
Epitrix hirtipennis (Melsheimer)	MX, US	Vegetative, roots	No	No	Anon., 1992; CPC, 2001
Epitrix subcrinita LeConte	MX, US	Vegetative, roots	No	No	MacGregor and Gutierrez, 1983; Metcalf and Metcalf, 1993
Lema nigrovittata Guerin	MX, US	Vegetative	No	No	MacGregor and Gutierrez, 1983
Leptinotarsa decemlineata (Say)	MX, US	Vegetative	No	No	Anon., 1992; CPC, 2001; MacGregor and Gutierrez, 1983; Metcalf and Metcalf, 1993
Plagiometriona clavata (F.)	MX, US	Vegetative	No	No	Arnett, 1993; McGuire and Crandall, 1967; Vencl *et al.*, 1999
Curculionidae					
Colecerus sp.	MX	Stem	Yes[2]	No	PPQ interception
Conotrachelus sp.	MX	Stem	Yes[2]	No	PPQ interception
Copturus sp.	MX	Tuber	Yes[2]	Yes	PPQ interception
Cylindrocopturus sp.	MX	Tuber	Yes[2]	Yes	PPQ interception
Diaprepes sp.	MX	Root	Yes[2]	No	PPQ interception

Pest	Geographic Distribution[1]	Plant Part Affected	Quarantine Pest	Likely to Follow Pathway	References
Epicaerus sp.	MX	Bulb, Stem, Tuber	Yes[2]	Yes	PPQ interception
Epicaerus cognatus Sharp	MX	Vegetative, Tuber	Yes	Yes	CPC, 2001; CEIR, 1959; MacGregor and Gutierrez, 1983
Hypera postica (Gyllenhal)	MX, US	Vegetative, stems	No	No	CPC, 2001; Hsiao, 1993; Martinez-Carillo and Carrillo-Sanchez, 1979; Metcalf and Metcalf, 1993
Pantomorus cervinus (Boheman)	MX, US	Vegetative, roots	No	No	CIE, 1966; CPC, 2001; Woodruff and Bullock, 1979
Phyrdenus muriceus Germar	MX, US (AZ, FL)	Vegetative, roots, Tuber	No	Yes	Alcázar and Cisneros, 1998; O'Brien and Wibmer, 1982; MacGregor and Gutierrez, 1983
Premnotrypes sp.	MX	Tuber	Yes[2]	Yes	PPQ interception
Sphenophorus sp.	MX	Tuber	Yes[2]	Yes	PPQ interception
Trichobaris sp.	MX	Stem	Yes[2]	No	PPQ interception
Trichobaris trinotata (Say)	MX, US	Stem	No	No	MacGregor and Gutierrez, 1983; Metcalf and Metcalf, 1993
Elateridae					
Conoderus laurenti (Guerin)	MX	Roots, Tuber	No[3]	Yes	PPQ interception
Meloidae					
Epicauta cinerea (Förster)	MX, US	Roots, Tuber	No	No	McGuire and Crandall, 1967; Metcalf and Metcalf, 1993
Epicauta corvine LeConte	MX, US	Vegetative	No	No	MacGregor and Gutierrez, 1983
Epicauta longicollis (LeConte)	MX, US	Vegetative	No	No	McGuire and Crandall, 1967
Epicauta maculata (Say)	MX, US	Vegetative	No	No	MacGregor and Gutierrez, 1983; Metcalf and Metcalf, 1993
Epicauta pardalis LeConte	MX	Vegetative	No	No	MacGregor and Gutierrez, 1983
Epicauta vittata (F.)	MX, US	Vegetative	No	No	McGuire and Crandall, 1967; Metcalf and Metcalf, 1993

Pest	Geographic Distribution[1]	Plant Part Affected	Quarantine Pest	Likely to Follow Pathway	References
Lytta quadrimaculata (Chevrolat)	MX, US	Vegetative	No	No	McGuire and Crandall, 1967
Scarabaeidae					
Diplotaxis sp.	MX	Tuber	Yes[2]	Yes	PPQ interception
Euphoria pulchella (Gory and Percheron)	MX, US	Vegetative, roots	No	No	Anon., 1974; McGuire and Crandall, 1967; Smith, 2001
Phyllophaga dentex Bates	MX, US	Vegetative, roots	No	No	McGuire and Crandall, 1967; Metcalf and Metcalf, 1993; Smith, 2001
Phyllophaga obsoleta (Blanchard)	MX	Vegetative, roots	Yes	No	Lopez and Gonzalez, 1999; Poole and Gentili, 1996
Phyllophaga setifera (Burmeister)	MX	Vegetative, roots	Yes	No	Lopez and Gonzalez, 1999; Poole and Gentili, 1996
Tenebrionidae					
Blapstinus sp.	MX	Tuber	Yes[2]	Yes	PPQ interception
Epitragus sp.	MX	Stem	Yes[2]	No	PPQ interception
DIPTERA					
Agromyzidae					
Liriomyza sativae Blanchard	MX, US	Vegetative	No	No	CABI/EPPO, 1997; CPC, 2001; Musgrave *et al.*, 1975; Spencer, 1985
Anthomyiidae					
Delia platura (Meigen)	MX, US	Tuber, underground stems	No	Yes	Anon., 1992; CPC, 2001; Griffiths, 1993; MacGregor and Gutierrez, 1983
Tephritidae					
Neotephritis finalis (Loew)	MX, US	Vegetative	No	No	Foote *et al.*, 1993
Oedicarena latifrons (Wulp)	MX, US (AZ)	Tuber	No	Yes	Foote *et al.*, 1993; Lopez and Gonzalez, 1999
HETEROPTERA					
Cixiidae					
Oliarus acicus Caldwell	MX, US	Vegetative	No	No	McGuire and Crandall, 1967
Coreidae					
Acanthocephala femorata (F.)	MX, US	Vegetative	No	No	Anon., 1974; Henry and Froeschner, 1988
Leptoglossus zonatus (Dallas)	MX	Vegetative	No	No	MacGregor and Gutierrez, 1983

Pest	Geographic Distribution[1]	Plant Part Affected	Quarantine Pest	Likely to Follow Pathway	References
Phthia picta Drury	MX, US	Vegetative	No	No	CPC, 2001; McGuire and Crandall, 1967
Lygaeidae					
Nysius ericae (Schilling)	MX, US	Vegetative	No	No	MacGregor and Gutierrez, 1983
Prytanes sp.	MX	Tuber	Yes[2]	Yes	PPQ interception
Miridae					
Lygus lineolaris (Palisot de Beauvois)	MX, US	Vegetative	No	No	Henry and Froeschner, 1988; Metcalf and Metcalf, 1993; Schaefer and Panizzi, 2000
Polymerus testaceipes (Stål)	MX, US (FL, TX)	Vegetative	No	No	Anon., 1974; Henry and Froeschner, 1988
Pentatomidae					
Arvelius albopunctatus (DeGeer)	MX, US	Vegetative	No	No	Henry and Froeschner, 1988; Metcalf and Metcalf, 1993; Schaefer and Panizzi, 2000
Euschistus sp.	MX	Tuber	Yes[2]	Yes	PPQ interception
Euschistus biformis Stål	MX, US	Vegetative	No	No	McGuire and Crandall, 1967
Murgantia histrionica (Hahn)	MX, US	Vegetative	No	No	MacGregor and Gutierrez, 1983; Metcalf and Metcalf, 1993
Rhopalidae					
Arhyssus lateralis (Say)	MX, US	Vegetative	No	No	Henry and Froeschner, 1988; McGuire and Crandall, 1967; Paskewitz and McPherson, 1993
Tingidae					
Gargaphia iridescens Champion	MX, US (AZ, CA, CO, NM, TX)	Vegetative	No	No	Anon., 1974; Henry and Froeschner, 1988
Gargaphia solani Heidemann	MX, US	Vegetative	No	No	Henry and Froeschner, 1988; Schaefer and Panizzi, 2000
HOMOPTERA					
Aleyrodidae					
Bemisia tabaci Gennadius	MX, US	Vegetative	No	No	CABI/EPPO, 1999; CPC, 2001; Metcalf and Metcalf, 1993

Pest	Geographic Distribution[1]	Plant Part Affected	Quarantine Pest	Likely to Follow Pathway	References
Trialeurodes vaporariorum (Westwood)	MX, US	Vegetative	No	No	CPC, 2001; MacGregor and Gutierrez, 1983; Metcalf and Metcalf, 1993
Aphididae					
Acyrthosiphon pisum (Harris)	MX, US,	Vegetative	No	No	CIE, 1982; MacGregor and Gutierrez, 1983; Metcalf and Metcalf, 1993
Aphis craccivora Koch	MX, US	Vegetative	No	No	Anon., 1974; CIE, 1983; Metcalf and Metcalf, 1993
Aphis fabae Scopoli	MX, US	Vegetative	No	No	CPC, 2001; Metcalf and Metcalf, 1993
Aphis gossypii Glover	MX, US	Vegetative	No	No	CIE, 1968; Metcalf and Metcalf, 1993
Aphis spiraecola Patch	MX, US	Vegetative	No	No	CIE, 1969; CPC, 2001; Lopez and Gonzalez, 1999
Aulacorthum solani (Kaltenbach)	MX, US	Vegetative	No	No	Blackman and Eastop, 1984; Lopez and Gonzalez, 1999
Hyperomyzus lactucae L.	MX, US	Vegetative	No	No	CPC, 2001
Macrosiphum euphorbiae (Thomas)	MX, US	Vegetative	No	No	Anon., 1992; Lopez and Gonzalez, 1999
Myzus persicae (Sulzer)	MX, US	Vegetative	No	No	Anon., 1992; Lopez and Gonzalez, 1999
Rhopalosiphum maidis (Fitch)	MX, US	Vegetative	No	No	CPC, 2001; Metcalf and Metcalf, 1993
Rhopalosiphum rufiabdominale (Sasaki)	MX, US	Vegetative, roots	No	No	CIE, 1971; CPC, 2001; Metcalf and Metcalf, 1993
Cicadellidae					
Empoasca abrupta DeLong	MX, US	Vegetative	No	No	Anon., 1974; CPC, 2001
Empoasca fabae (Harris)	MX, US	Vegetative	No	No	MacGregor and Gutierrez, 1983; Metcalf and Metcalf, 1993
Empoasca kraemeri Ross & Moore	MX, US	Vegetative	No	No	Anon., 1974; CPC, 2001
Macrosteles fascifrons (Stål)	MX, US	Vegetative	No	No	MacGregor and Gutierrez, 1983; Metcalf and Metcalf, 1993

Pest	Geographic Distribution[1]	Plant Part Affected	Quarantine Pest	Likely to Follow Pathway	References
Membracidae					
Spissistilus festinus (Say)	MX, US	Vegetative	No	No	Arnett, 1993; McGuire and Crandall, 1967
Ortheziidae					
Orthezia insignis Browne	MX, US	Vegetative	No	No	Metcalf and Metcalf, 1993; Morrison, 1952
Pseudococcidae					
Dysmicoccus brevipes (Cockerell)	MX, US	Vegetative, roots	No	No	Ben-Dov, 1994
Nipaecoccus nipae (Maskell)	MX, US	Vegetative	No	No	Ben-Dov, 1994
Nipaecoccus viridis (Newstead)	MX	Vegetative	Yes	No	Ben-Dov, 1994
Phenacoccus gossypii Townsend & Cockerell	MX, US (FL, TX)	Vegetative	No	No	Ben-Dov, 1994; MacGregor and Gutierrez, 1983
Phenacoccus madeirensis Green	MX, US	Vegetative	Yes	No	Ben-Dov, 1994; CPC, 2001
Planococcus sp.	MX	Fruit	Yes[2]	No	PPQ interception
Planococcus citri (Risso)	MX, US (CA, FL)	Vegetative, roots	No	No	Ben-Dov, 1994; CPC, 2001
Pseudococcus calceolariae (Maskell)	MX, US (CA)	Vegetative	No	No	Ben-Dov, 1994; CPC, 2001
Pseudococcus jackbeardsleyi Gimpel and Miller	MX, US	Vegetative	No	No	CPC, 2001; Gimpel and Miller, 1996; Scalenet, 2002
Pseudococcus longispinus (Targioni-Tozzetti)	MX, US	Vegetative	No	No	Ben-Dov, 1994; CPC, 2001
Psyllidae					
Paratrioza cockerelli (Sulc)	MX, US	Vegetative	No	No	MacGregor and Gutierrez, 1983; Metcalf and Metcalf, 1993
LEPIDOPTERA					
Gelechiidae					
Keiferia lycopersicella Walsingham	MX, US	Vegetative	No	No	Anon., 1992; Lopez and Gonzalez, 1999; Zhang, 1994
Phthorimaea operculella (Zeller)	MX, US	Tuber	No	Yes	Llanderal *et al.*, 1996; Lopez and Gonzalez, 1999; Metcalf and Metcalf, 1993
Hesperiidae					
Urbanus proteus (L.)	MX, US	Vegetative	No	No	Arnett, 1993; MacGregor and Gutierrez, 1983

Pest	Geographic Distribution[1]	Plant Part Affected	Quarantine Pest	Likely to Follow Pathway	References
Noctuidae					
Agrotis ipsilon Hufnagel	MX, US	Vegetative; Tuber	No	No	Anon., 1992; Lopez and Gonzalez, 1999; Zhang, 1994
Feltia subterranea (F.)	MX, US	Roots, underground stems	No	No	CPC, 2001; Lopez and Gonzalez, 1999; Metcalf and Metcalf, 1993
Copitarsia consueta (Walker)	MX	Vegetative	Yes	No	MacGregor and Gutierrez, 1983; McGuire and Crandall, 1967
Copitarsia turbata Herrich-Schäffer	MX	Vegetative	Yes	No	McGuire and Crandall, 1967; Zhang, 1994
Mamestra configurata Walker	MX, US	Vegetative	No	No	CPC, 2001; Crumb, 1956; Poole, 1989
Pseudaletia unipuncta Haworth	MX, US	Vegetative	No	No	CIE, 1967; Lopez and Gonzalez, 1999; Poole, 1989
Peridroma saucia Hübner	MX, US	Vegetative	No	No	Anon., 1992; CPC, 2001; Poole, 1989
Spodoptera eridania Stoll	MX, US	Vegetative	No	No	CPC, 2001; Metcalf and Metcalf, 1993; Poole, 1989
Spodoptera exigua Hübner	MX, US	Vegetative	No	No	Lopez and Gonzalez, 1999; Metcalf and Metcalf, 1993; Poole, 1989
Spodoptera frugiperda J.E. Smith	MX, US	Vegetative	No	No	Lopez and Gonzalez, 1999; Metcalf and Metcalf, 1993; Poole, 1989
Spodoptera ornithogalli (Guenée)	MX, US	Vegetative	No	No	Anon., 1992; Lopez and Gonzalez, 1999
Trichoplusia ni (Hübner)	MX, US	Vegetative	No	No	Landolt, 2001; Lopez and Gonzalez, 1999
Xestia c-nigrum L.	MX, US	Vegetative	No	No	CPC, 2001; Lafontaine, 1998
Sphingidae					
Manduca quinquemaculata (Haworth)	MX, US	Vegetative	No	No	MacGregor and Gutierrez, 1983; Metcalf and Metcalf, 1993
Manduca sexta (L.)	MX, US	Vegetative	No	No	MacGregor and Gutierrez, 1983; Metcalf and Metcalf, 1993

Pest	Geographic Distribution[1]	Plant Part Affected	Quarantine Pest	Likely to Follow Pathway	References
ORTHOPTERA					
Gryllidae					
Gryllus assimilis (F.)	MX, US	Vegetative	No	No	MacGregor and Gutierrez, 1983; Metcalf and Metcalf, 1993
THYSANOPTERA					
Thripidae					
Thrips tabaci Lindeman	MX, US	Vegetative	No	No	CPC, 2001; Metcalf and Metcalf, 1993; Powell and Landis, 1965
VIROID					
Potato spindle tuber	MX, US	Whole plant	No	Yes	CPC, 2001; Jeffries 1998
VIRUSES					
Bromoviridae					
Alfalfa mosaic	MX, US	Vegetative	No	Yes	CPC, 2001; Stevenson *et al*., 2001
Cucumber mosaic	MX, US	Vegetative	No	Yes	CPC, 2001; Stevenson *et al.* 2001
Bromoviridae: Ilarvirus					
Tobacco streak	MX, US	Vegetative	No	Yes	CPC, 2001; NAPPO, 2003; Stevenson *et al*., 2001
Bunyaviridae: Tospovirus					
Tomato spotted wilt	MX, US	Vegetative	No	Yes	CPC, 2001; Moyer, 2002 ; NAPPO, 2003; Stevenson, *et al*., 2001
Carlavirus					
Potato virus M	MX, US	Tuber	No	Yes	CPC, 2001; Stevenson *et al*., 2001
Potato virus S	MX, US	Tuber	No	Yes	CPC, 2001; Stevenson *et al*., 2001
Geminiviridae (Curtovirus subgroup III)					
Beet curly top	MX, US	Vegetative	No	Yes	CPC, 2001; NAPPO,2003; Stevenson, *et al*., 2001
Luteovirus					
Potato leafroll	MX, US	Tuber	No	Yes	Stevenson *et al*., 2001
Necrovirus					
Tobacco necrosis	MX, US	Root	No	Yes	CPC, 2001; NAPPO, 2003; Stevenson *et al*., 2001
Potexvirus					
Potato aucuba mosaic	MX, US	Vegetative	No	Yes	Stevenson, *et al*., 2001

Pest	Geographic Distribution[1]	Plant Part Affected	Quarantine Pest	Likely to Follow Pathway	References
Potato latent	MX, US	Tuber	No	Yes	Stevenson, *et al.*, 2001
Potato virus X	MX, US	Tuber	No	Yes	Stevenson *et al.*, 2001
Potyviridae					
Potato virus A	MX, US	Tuber	No	Yes	Stevenson *et al.*, 2001
Potato virus Y	MX, US	Vegetative	No	Yes	Stevenson *et al.*, 2001
Sobemovirus					
Sowbane mosaic	MX, US	Vegetative	No	Yes	Stevenson *et al.*, 2001
Tobamovirus					
Tobacco mosaic	MX, US	Vegetative	No	Yes	Stevenson *et al.*, 2001
Tomato mosaic	MX, US	Vegetative	No	Yes	Stevenson *et al.*, 2001
BACTERIA					
Erwinia carotovora subsp. *atroseptica* (van Hall) Dye (Enterobacteriales)	MX, US	Vegetative (Leaf, Stem)	No	Yes	CPC, 2001
Erwinia carotovora subsp. *carotovora* (Jones) Bergey (Enterobacteriales)	MX, US	Vegetative	No	Yes	CPC, 2001
Pseudomonas syringae van Hall (Pseudomonadales)	MX, US	Leaf	No	No	CPC, 2001
Pseudomonas syringae pv. *tabaci* (Wolf & Foster) Young (Pseudomonadales)	MX, US	Leaf	No	No	CPC, 2001
Ralstonia solanacearum race 3 (Smith) Yabuuchi *et al*. (Burkholderiales)	MX, US[4]	Vegetative	Yes	Yes	NAPPO, 2003
Rhizobium radiobacter (Beij. & Deld.) Pribam. (Rhizobiales)	MX, US	Vegetative	No	Yes	CPC, 2001
Streptomyces scabiei (Thaxter) Lambert & Loria (Actinomycetales)	MX, US	Leaf, stem, root, tuber	No	Yes	CPC, 2001; NAPPO, 2003
FUNGI					
Angiosorus solani Thirum. & O'Brien (= *Thecaphora solani* [Thirum & O'Brien] Mordue) (Basidiomycota: Ustilaginales)	MX	Stem, tuber	Yes	Yes	EPPO, 1997; Stevenson *et al.*, 2001
Athelia rolfsii (Curzi) Tu & Kimbrough (= *Corticium rolfsii* Curzi) (Basidiomycota: Stereales)	MX, US	Vegetative	No	Yes	CPC, 2001
Cladosporium sp.	MX	Stem, Tuber	Yes[2]	Yes	PPQ interception

Pest	Geographic Distribution[1]	Plant Part Affected	Quarantine Pest	Likely to Follow Pathway	References
Cochliobolus lunatus R. R. Nelson & Haasis (Ascomycota: Dothideales)	MX, US	Inflorescence, leaf, seed	No	Yes	CPC, 2001; Farr *et al.*, 1989
Coniothyrium sp.	MX	Tuber	Yes[2]	Yes	PPQ interception
Didymella bryoniae (Auersw.) Rehm (Ascomycota: Dothideales)	MX, US	Vegetative	No	Yes	CPC, 2001; Farr *et al.*, 1989
Didymella lycopersici Kleb. (Ascomycota: Dothideales)	MX, US	Vegetative	No	Yes	CPC, 2001; Farr *et al.*, 1989; Morgan-Jones and Burch, 1988
Fusarium sp.	MX	Stem, Tuber	Yes[2]	Yes	PPQ interception
Gibberella zeae (Schwein.) Petch (Ascomycota: Hypocreales)	MX, US	Vegetative	No	Yes	CPC, 2001; Farr *et al.*, 1989
Helminthosporium solani Durieu & Mont. (Fungi Imperfecti: Hyphomycetes)	MX, US	Leaf, stem, tuber	No	Yes	CPC, 2001; Farr *et al.*, 1989
Leveillula taurica (Lev.) G. Arnaud (Ascomycota: Erysiphales)	MX, US	Leaf, stem	No	No	CPC, 2001; Farr *et al.*, 1989
Macrophomina phaseolina (Tassi) Goid. (Fungi Imperfecti: Hyphomycetes)	MX, US	Leaf, root, seed, stem, tuber	No	Yes	CPC, 2001; Farr *et al.*, 1989
Microsphaeropsis sp.	MX	Stem	Yes[2]	No	PPQ interception
Phoma sp.	MX	?	Yes[2]	?	PPQ interception
Phytophthora capsici Leonian (Oomycota: Pythiaceae)	MX, US	Stems	No	No	CPC, 2001; Farr *et al.*, 1989
Phytophthora citrophthora (Sm. & Sm.) Leonian (Oomycota: Pythiaceae)	MX, US	Vegetative	No	Yes	CPC, 2001; Farr *et al.*, 1989
Phytophthora infestans (Mont.) de Bary (Oomycota: Pythiaceae)	MX, US	Vegetative	No	Yes	CPC, 2001; Farr *et al.*, 1989
Puccinia pittieriana Henn. (Basidiomycota: Uredinales)	MX	Inflorescence, Leaf, Stem	Yes	No	CPC, 2001; EPPO, 1997
Pythium aphanidermatum (Edson) Fitzp. (Oomycota: Pythiales)	MX, US	Vegetative	No	Yes	CPC, 2001; Farr *et al.*, 1989
Rosellinia bunodes (Berk. & Broome) Sacc. (Ascomycota: Xylariales)	MX	Root, Stem, Tuber	Yes	Yes	CPC, 2001; Stevenson *et al.*, 2001

Pest	Geographic Distribution[1]	Plant Part Affected	Quarantine Pest	Likely to Follow Pathway	References
Rosellinia necatrix Prill. (Ascomycota: Xylariales)	MX, US	Vegetative	No	Yes	CPC, 2001; Farr *et al.*, 1989
Sclerotinia sclerotiorum (Lib.) de Bary (Ascomycota: Leotiales)	MX, US	Vegetative	No	Yes	CPC, 2001; Farr *et al.*, 1989
Spongospora subterranea f.sp. *subterranea* (Wallr.) Lagerh. (Protozoa: Plasmodiophorales)	MX, US	Vegetative	No	Yes	CPC, 2001; Farr *et al.*, 1989; NAPPO, 2003
Verticillium albo-atrum Reinke & Berthier (Fungi Imperfecti: Hyphomycetes)	MX, US	Vegetative	No	Yes	CPC, 2001; Farr *et al.*, 1989
Verticillium dahliae Kleb. (Fungi Imperfecti: Hyphomycetes)	MX, US	Vegetative	No	Yes	CPC, 2001; Farr *et al.*, 1989
NEMATODES					
Belonolaimidae					
Belonolaimus longicaudatus Rau	MX, US	Root	No	Yes	CPC, 2001
Criconematidae					
Criconemella sp.	MX	Root, Tuber	Yes[2]	Yes	CPC, 2001
Anguinidae					
Ditylenchus destructor Thorne	MX, US	Root, Tuber	No	Yes	CPC, 2001
Ditylenchus dipsaci (Kühn) Filipjev	MX, US	Root, Tuber	No	Yes	CPC, 2001
Heteroderidae					
Globodera pallida (Stone) Behrens	MX	Root, Tuber	Yes	Yes	SON, 2002; CPC, 2001
Globodera rostochiensis (Wollen.) Behrens	MX, US (NY)	Root, Tuber	Yes	Yes	CPC, 2001
Globodera tabacum (Lownsbery) Behrens	MX, US	Root, Tuber	No	Yes	CPC, 2001
Hoplolaimidae					
Helicotylenchus dihystera (Cobb) Sher.	MX, US	Root, Tuber	No	Yes	CPC, 2001
Meloidogynidae					
Meloidogyne chitwoodi Golden *et al.*	MX, US	Root, Tuber	No	Yes	CPC, 2001
Meloidogyne incognita (Kofoid & White) Chitwood	MX, US	Root, tuber	No	Yes	CPC, 2001
Meloidogyne javanica (Treb) Chitwood	MX, US	Root, tuber	No	Yes	CPC, 2001

Pest	Geographic Distribution[1]	Plant Part Affected	Quarantine Pest	Likely to Follow Pathway	References
Pratylenchidae					
Nacobbus aberrans Thorne & Allen	MX, US[5]	Root, tuber	No	Yes	CPC, 2001; SON, 2002
Pratylenchus brachyurus (Godfrey) Filipjev *et al.*	MX, US	Vegetative	No	Yes	CPC, 2001
Pratylenchus coffeae (Zimmermann) Filipjev *et al.*	MX, US	Vegetative	No	Yes	CPC, 2001
Pratylenchus penetrans (Cobb) Filipjev *et al.*	MX, US	Vegetative	No	Yes	CPC, 2001
Pratylenchus thornei Sher & Allen	MX, US	Vegetative	No	Yes	CPC, 2001
Rotylenchulidae					
Rotylenchulus reniformis Linford & Oliviera	MX, US	Root	No	No	CPC, 2001
Longidoridae					
Longidorus sp.	MX	Vegetative (Leaf, Root)	Yes[2]	Yes	CPC, 2001
Xiphinema americanum Cobb.	MX, US	Root	No	No	CPC, 2001

[1]Distribution (specific states are listed only if distribution is limited): AZ = Arizona; CA = California; CO = Colorado; FL = Florida; MX = Mexico; NM = New Mexico; NY = New York; TX = Texas; US = United States (widely distributed).
[2]Organisms listed at the level of genus, although regarded as quarantine pests because of their uncertain identity, were not considered for further analysis for lack of evidence that they posed risks.
[3]Record based on a single port interception (PIN 309), and may refer to *Heteroderes laurentii* Guérin-Meneville, a pest of potato that occurs in the United States (Cockerham and Deen, 1936). The genera *Heteroderes* and *Conoderus* are considered synonyms by some authors (e.g., Hill, 1994).
[4]Detected in geranium; not known to occur in potatoes in the United States.
[5]The potato subgroup of this nematode is not known to occur in the United States.

The hazards posed by organisms identified only to order, family or genus were not assessed if no additional evidence existed regarding quarantine pests in the same taxa or if this information was considered elsewhere. However, if pest identification is refined in the future or additional evidence is found, then a reevaluation of their risk may occur. Lack of species identification may indicate the limits of current taxonomic knowledge or the life stage or the quality of the specimen submitted for identification. Pest risk assessments focus on available information and are dynamic and responsive to relevant, new data.

Some plant pests listed in Table 3 that were not chosen for further scrutiny may be potentially detrimental to the agricultural systems of the United States. There were a variety of reasons for not subjecting them to further analysis. The primary association of the pests may be with plant parts other than the commodity proposed to be imported, and therefore the pests are unlikely to be associated with the commodity during transport or processing, or the pests may be associated with the commodity as biological contaminants, but are not expected to be present in every shipment. These pests are indicated in Table 3 as not following the pathway.

Quarantine pests that are likely to follow the pathway, *i.e.*, be included in commercial shipments of potato from Mexico (Table 4), are subjected to steps 5 through 7 below.

Table 4. Quarantine Pests Selected for Further Analysis.

Arthropod
Epicaerus cognatus Sharp (Coleoptera: Curculionidae)
Bacterium
Ralstonia solanacearum race 3 (Smith) Yabuuchi *et al.* (Burkholderiales)
Fungi
Angiosorus solani Thirum. & O'Brien (Basidiomycota: Ustilaginales)
Rosellinia bunodes (Berk. & Broome) Sacc. (Ascomycota: Xylariales)
Nematodes
Globodera pallida (Stone) Behrens (Heteroderidae)
Globodera rostochiensis (Wollen.) Behrens (Heteroderidae)
Nacobbus aberrans Thorne & Allen (Pratylenchidae)

5. Consequences of Introduction—Economic/Environmental Importance

Potential consequences of introduction are rated using five risk elements: Climate-Host Interaction, Host Range, Dispersal Potential, Economic Impact, and Environmental Impact. These elements reflect the biology, host ranges, and climatic/geographic distributions of the pests. For each risk element, pests are assigned a rating of Low (1 point), Medium (2 points), or High (3 points) (PPQ, 2000). A Cumulative Risk Rating is then calculated by summing all risk element values. The values determined for the Consequences of Introduction for each pest are summarized in Table 5.

The major sources of uncertainty present in this risk assessment are similar to those in other risk assessments. They include the use of a developing or evolving process, such as the PPQ Risk Assessment Guidelines (PPQ, 2000), the approach used to combine risk elements (Bier, 1999; Morgan and Henrion, 1990), the evaluation of risk by comparisons to lists of factors within the guidelines (Kaplan, 1992), the quality of the biological information (Gallegos and Bonano, 1993), and the inherent biological variation within a population of organisms (Morgan and Henrion, 1990). To address uncertainty, the lists of factors were interpreted as illustrative and not exhaustive. This implies that additional biological information, even if not explicitly part of the criteria, can be used when it informs a rating.

Climate-Host Interaction

<u>Insect</u>

Epicaerus cognatus is distributed in the mountainous states of Mexico (Mexico City, and States of Puebla, Tlaxcala, Vera Cruz, Hidalgo, and Mexico) (CEIR, 1959). The climates in these areas correspond to those in the United States in Plant Hardiness Zones 9 to 11; thus the rating is Medium (2).

Nematodes

Soil and climatic conditions in all major potato production areas of North America are suitable for the development of potato cyst nematodes (*Globodera rostochiensis* and *G. pallida*) making these nematodes a threat to the entire potato industry (Brodie, 2001). Potato cyst nematodes coevolved with their preferred hosts *Solanum* spp.; one or both nematodes is known to occur in at least 58 countries in Europe, Asia, Africa, the Americas, and Oceania (Stevenson *et al.*, 2001). *Globodera rostochiensis* occurs in New York, was eradicated from Delaware (CPC, 2001), and is under Official Control by PPQ. Both *Globodera* species appear to be capable of establishing in Plant Hardiness Zones 4 to 7. For these reasons, the rating is High (3).

Based on host preference field studies, *Nacobbus aberrans* has three subgroups. Of these, only the potato subgroup does not occur in the United States (SON, 2002). If this subgroup is similar to the other taxonomically distinct subgroups, *N. aberrans* appears capable of establishing in most areas of the United States (Plant Hardiness Zones 2 to 7 or 8). For these reasons, the rating is High (3).

Bacterium

Ralstonia solanacearum race 3, a pathogen that is widespread in tropical, subtropical and warm temperate areas, was reported in a number of European countries in the 1990s (CPC, 2001). It is capable of establishing populations throughout all of the potato-producing areas of the United States (Plant Hardiness Zones 2 to 5). For these reasons, the rating is High (3).

Fungi

Angiosorus solani occurs in Bolivia, Chile, Colombia, Peru and Mexico (EPPO, 1997; Stevenson *et al*., 2001). It is prevalent in cool, mountainous regions, and occurs in warm coastal climes (Stevenson, *et al*., 2001). It is capable of establishing populations throughout all of the potato-producing areas of the United States (Plant Hardiness Zones 2 to 5). For these reasons, the rating is High (3).

Rosellinia bunodes is reported from Bolivia, Chile, Ecuador, Mexico, Panama and Venezuela, and there is an unconfirmed report of its occurrence in New York (CPC, 2001). This fungus is prevalent in the tropics wherever cool to warm, moist conditions occur (CPC, 2001). It is capable of establishing populations in potato-producing areas of the United States (Plant Hardiness Zones 3 to 6). For these reasons, the rating is High (3).

Host Range

The host range for *E. cognatus* appears to be limited to the genus *Solanum* (CEIR, 1959; CPC, 2001). The rating is therefore Low (1).

Besides potato, hosts of *R. solanacearum* race 3 include other species of Solanaceae, such as *Solanum dulcamara*, *S. nigrum*, *S. cinereum* and *Lycopersicon esculentum* (CPC, 2001). Other hosts are *Urtica dioica* (Urticaceae); *Portulaca oleracea* (Portulacaceae); *Polygonum capitata* (Polygonaceae); *Pelargonium* sp. (Geraniaceae); and *Melampodium perfoliatum*, *Galinsoga parviflora*, and *G. ciliata* (Asteraceae). Because of its broad host range, this pathogen is rated High (3).

The host ranges for *G. pallida* and *G. rostochiensis* include members of the genus *Solanum* and the genera *Datura, Oxalis* and *Salpiglossis* (CPC, 2001), which are in multiple plant families. Therefore, both pests are rated High (3). The host range for *N. aberrans* includes members of the Solanaceae and the genera *Beta, Brassica, Cucumis, Daucus, Ipomoea, Lactuca,* and *Pisum* (CPC, 2001), which are in several other plant families. Thus, the species is rated High (3).

The host range of *A. solani* is restricted to the Solanaceae, specifically members of the genus *Solanum, L. esculentum*, and the weed, *Datura stramonium* (EPPO, 1997; SBML, 2003). For this reason, the rating is Medium (2).

Rosellinia bunodes is a polyphagous pathogen, attacking plants in several families, including Rutaceae, Rubiaceae, Euphorbiaceae, Marantaceae, Myristicaceae, and Sterculiaceae, as well as Solanaceae (CPC, 2001). For this reason the rating is High (3).

Dispersal Potential

Female *E. cognatus* oviposit in batches of 10-15 eggs on foliage over several months (CEIR, 1959). Larvae may feed within tubers for several months. There is only one generation per year. No information is available on the natural dispersal capacity of this insect or its dispersal via commerce, although records indicate that it has been intercepted at U.S. ports numerous times in potato tubers (PIN 309) and, thus, might be dispersed readily via this pathway. Because of this uncertainty and the rather low indicated fecundity, risk is estimated to be Medium (2) for this element.

The nematodes *G. pallida*, *G. rostochiensis*, and *N. aberrans* are dispersed in soil debris and contaminated plant material in addition to infected tubers (SON, 2002; Stevenson *et al*., 2001). These nematodes generally have short life cycles and produce numerous eggs per female; the infective juvenile is the dispersal stage (SON, 2002; Stevenson *et al*., 2001). These species thus have both high dispersal and reproductive potentials, and are rated High (3).

Although *Ralstonia solanacearum* race 3 may take years to spread from field to field through natural groundwater supplies (CPC, 2001; Stevenson *et al.*, 2001), it is rapidly and widely spread through latently infected potatoes and in surface irrigation water (Stevenson *et al.*, 2001). High soil moisture and periods of wet weather are associated with high disease severity. This race shows high virulence, particularly when associated with potato or tomato (CPC, 2001). The rating thus is High (3).

Angiosorus solani is dispersed in soil debris and in contaminated plant material, in addition to infected potato tubers (EPPO, 1997; Stevenson *et al*., 2001). Infected tubers are the primary initial sources of field contamination (Stevenson *et al*., 2001). Malformed tubers are conspicuous; however, latent infection may be at undetectable levels or spores may be present on the surface of healthy tubers, so dispersal on infected, symptomless tubers is likely (EPPO, 1997). The rating for this pest is High (3).

Rosellinia bunodes remains active in soil and infected vegetable matter (e.g., Wolar, 1972), and thus could be dispersed in infected potato tubers, as occurs in other *Rosellinia* spp. (Stevenson *et* *al*., 2001). Because of the uncertainty surrounding its dispersal potential in potato, this pest is given a risk rating of High (3).

Economic Impact

Larvae of *E. cognatus* are said to cause severe damage to potato tubers through their extensive feeding and tunneling (CEIR, 1959). Such damage would result in lower yield and reduced value of the crop. Introduction of this pest into the United States could result in a loss of foreign or domestic markets for potatoes. Because of its potential to cause significant economic harm, the pest is rated High (3) for this risk element.

Among the pathogens, *R. solanacearum* has been reported to cause high losses in potatoes (CPC, 2001). In Nepal, tuber rotting occurred in an average of 10% of stored potatoes with a maximum of 50% in some cases; crop losses on small farms may reach 100%. *Angiosorus solani* has been reported to reduce potato tuber yields by up to 85% (Stevenson *et al*., 2001). *Rosellinia bunodes* is considered an important root disease of coffee in India (Govindarajan, 1988). In Argentina, this fungus was reported to have killed an entire stand of the tree *Melia azedarach* within 5-6 years of infection (Wolar, 1972). A mortality rate of 20% in cocoa was reported in Brazil (Feitosa & Pimentel, 1991).

The economic damage caused by *G. pallida* and *G. rostochiensis* can be severe. If left uncontrolled these nematodes can cause up to 80% loss in yield (Brodie, 2001). In the United Kingdom, depending on egg loads in soil, losses ranged from 6.25 t/ha to 22 t/ha (CPC, 2001). In Norway, continuous cropping of susceptible potato cultivars resulted in an average yield loss of 50-60%. Losses of 30% were reported in India. Yield reductions caused by *N. aberrans* may be as high as 90% in some crops (CPC, 2001). Applications of nematicides often are necessary to produce acceptable yields (CPC, 2001).

Introduction of these pathogens could result in a loss of domestic or foreign markets for U.S.-grown potatoes and other commodities. For example, all three nematodes are listed by the European and Mediterranean Plant Protection Organization as quarantine pests for Europe (EPPO, 1997).

All of the pests are expected to reduce the value of potato and other crops by increasing the costs of production. For example, Merchan (1993) discussed the chemical, biological, and cultural methods necessary for the control of *R. bunodes* in coffee, cocoa, and forest trees. All are therefore given ratings of High (3).

Environmental Impact

The environmental impact rating reflects the potential for these quarantine pests adversely to affect native species outside of the potato agroecosystem (PPQ, 2000).

None of the pests is expected to stimulate the initiation of biological or chemical control programs. Those already in place for the control of established potato pests would be expected to be equally effective against similar introduced pests.

The host ranges of *E. cognatus* and *A. solani* appear largely to be limited to the Solanaceae. This family has many native and naturalized plants within U.S. ecosystems that are particularly common along roadsides and disturbed sites (Gleason and Cronquist, 1991). The relatively low density of these plants as a component in native stands, however, means that pest infestations are not expected adversely to affect the competitive abilities of these plants in the long term since high plant densities generally are associated with high pest infestation rates (Agrios, 1997; Rabb and Guthrie, 1970). The genetic uniformity of monoculture cropping systems generally does not occur in natural plant populations. This makes it more likely that the natural population will have resistance to a number of potential pests (Agrios, 1997; Rabb and Guthrie, 1970). Animals relying on these plants for food, habitat, or as breeding sites are not likely to be affected by minimally reduced plant growth. The only Threatened or Endangered plant species (50 CFR §17.12) in the Solanaceae exist in Hawaii and Puerto Rico (e.g., *Solanum drymophilum*, *S. incompletum*, *S. sandwicense*) (NatureServe, 2002; USFWS, 2002). For the above reasons, the rating for both of the pests is Low (1).

The relatively larger host ranges of the other pathogens suggest that more native plant species have the potential to be harmed, although the most severe epidemics of these pathogens are associated only with growth or yield reduction and not death. The greater vulnerability of native plant associations and potential for ecological disruption are reflected in a risk rating of High (3).

Table 5. Consequences of Introduction for Potatoes from Mexico

Pest	Climate/Host	Host Range	Dispersal Potential	Economic Impact	Environmental Impact	Cumulative Risk Rating
Epicaerus cognatus	Medium (2)	Low (1)	Medium (2)	High (3)	Low (1)	Medium (9)
Globodera pallida	High (3)	High (3)	High (3)	High (3)	High (3)	High (15)
Globodera rostochiensis	Medium (2)	High (3)	High (3)	High (3)	High (3)	High (14)
Nacobbus aberrans	High (3)	High (3)	High (3)	High (3)	High (3)	High (15)
Ralstonia solanacearum race 3	High (3)	High (3)	High (3)	High (3)	High (3)	High (15)
Angiosorus solani	High (3)	Medium (2)	High (3)	High (3)	Low (1)	Medium (12)
Rosellinia bunodes	High (3)	High (3)	High (3)	High (3)	High (3)	High (15)

6. Likelihood of Introduction—Quantity Imported and Pest Opportunity

Likelihood of introduction is a function of both the quantity of the commodity imported annually and pest opportunity, which is based on five criteria that consider the potential for pest survival along the pathway (PPQ, 2000) (Table 6).

Quantity Imported Annually

The rating for the Quantity Imported Annually is usually based on the amount reported by the exporting country, and is converted into standard units of 40-foot-long shipping containers. The quantity of table stock potatoes to be imported annually from Mexico by the United States currently is unknown. It is estimated that imports are unlikely to exceed 1% of production (W. Snell, APHIS-PPQ-PIM, personal communication), which totaled 1,536,400 tonnes in 2002 (FAOSTAT, 2003). However, even this projected volume of potatoes to be imported from Mexico will fill approximately 620 40-foot-long shipping containers. The rating for the Quantity Imported Annually therefore is High (3).

Survive Postharvest Treatments

Generally, insect pests of potato are controlled with chemical applications during the growing season. Borers, such as larvae of *E. cognatus*, are unlikely to be detected by visual examination (Anon., 1992). For that reason, this pest is estimated to have a high probability of surviving postharvest treatments and risk is rated High (3).

Control of pathogens in potato production generally involves exclusion, sensitive detection methods and sanitation (Stevenson *et al*., 2001). Pathogens may infect the tubers directly or be present in soil contaminating the tubers (CPC, 2001). Nematodes generally are limited by phytosanitary measures aimed at excluding these pests because other potato treatments are not effective in eliminating latent infection (Stevenson *et al*., 2001). The only postharvest treatment currently permitted for the control of nematodes in potatoes is methyl bromide (USDA, 2002a). Despite the existence of various mitigative practices, the specific phytosanitary measures that may be applied in Mexico and their efficacy are not presently known. Because of this uncertainty, and the fact that latent infections may go undetected, the pathogens also are estimated to have a high probability of surviving postharvest treatments.

Survive Shipment

All of the pests are likely to survive shipment for they are internal and protected within the tuber or may be present in soil in a resting stage (Alcazar and Cisneros, 1998; Anon., 1992; CIP, 1996; CPC, 2001). If the tuber remains viable, then the pathogens will remain viable and infective (Jeffries, 1998; Stevenson *et al*., 2001). Fungal spores and sclerotia are likely to survive the conditions under which potatoes are shipped because ambient light and air will not reduce viability (Agrios, 1997). For these reasons, the rating is High (3) for all of the pests.

Not Detected at the Port-of-Entry

As in assessing the risk of potato pests surviving post-harvest treatment, estimating the risk that these pests will not be detected at a port-of-entry involves consideration of their degree of concealment. *Epicaerus cognatus* would be difficult to detect at ports-of-entry because of its internal location within the tuber (CEIR, 1959). The pathogens are microscopic, and cannot be detected because the tubers may appear symptomless (Anon., 1992; Jeffries, 1998; Stevenson *et al*., 2001). Latent infections are undetected by visual inspection, and reliable detection, by laboratory assays (7 CFR §319.37-1), may take an unacceptably long time even if an infrastructure exists to sample and assay the plant material (Agrios, 1997; Jeffries, 1998). The time needed to assay depends on the pest, and some assays may take weeks (Jeffries, 1998). This is incompatible with the pace of port decisions that often are made within days (7 CFR §319.4[b]). If nematode cysts are present at low densities, no distinct symptoms are present, and the symptoms that appear at high population densities are of limited diagnostic value (Stevenson *et al*., 2001). It is difficult and may be impractical to produce field-grown potatoes totally free of contaminants, such as soil; thus pests are likely to escape detection. For these reasons, the rating is High (3) for all of the pests.

Moved to a Suitable Habitat

Potatoes are sold all over the United States, and those imported from Mexico could be shipped to markets in every state. As noted above, all of the pathogens are expected to be able to survive over a broad geographic range in the United States, and are therefore rated High (3). Because of its highly restricted range in the tropics, *E. cognatus* likely would be able to survive only in the southernmost United States. Its rating is Medium (2).

Contact with Host Material

Potatoes latently infected with pathogens, such as *R. solanacearum*, present a risk if they come into contact with potential hosts. For example, if tubers carry latent *R. solanacearum* infection, there is the potential for the bacterium to find it's way into waterways where natural hosts, such as *Solanum dulcamara*, are present (El-Nashaar, 2003). Via this avenue, the bacterium could become established and spread. Establishment and spread of this bacterium via contaminated potato peel waste from potato processing facilities, and estimated losses, are well documented in the literature (ECC, 2003).

Ralstonia solanacearum race 3, *R. bunodes*, and the nematodes have been recorded from numerous host species in several families, many of which are widely distributed within the United States. In Mexico, potatoes are available the year round (CIP, 2002), and can be exported to the United States during the potato growing season. Suitable host material thus could be available to promote the survival of these pests. The pests with more restricted host ranges also could find suitable hosts. For example, *A. solani* has been recorded from *Datura stramonium* (jimsonweed), which is found in at least 48 states (USDA, 2002b). Potatoes are grown in at least 35 states, and other species of *Solanum* are widespread (USDA, 2002b). For all of the pests, the rating thus is High (3).

Table 6. Likelihood of Introduction for Pests of Potatoes from Mexico

Pest	Quantity Imported Annually	Survive Postharvest Treatment	Survive Shipment	Not Detected at Port of Entry	Moved to Suitable Habitat	Contact with Host Material	Cumulative Risk Rating
Epicaerus cognatus	High (3)	High (3)	High (3)	High (3)	Medium (2)	High (3)	High (17)
Globodera pallida	High (3)	High (3)	High (3)	High (3)	High (3)	High (3)	High (18)
Globodera rostochiensis	High (3)	High (3)	High (3)	High (3)	High (3)	High (3)	High (18)
Nacobbus aberrans	High (3)	High (3)	High (3)	High (3)	High (3)	High (3)	High (18)
Ralstonia solanacearum race 3	High (3)	High (3)	High (3)	High (3)	High (3)	High (3)	High (18)

Pest	Quantity Imported Annually	Survive Postharvest Treatment	Survive Shipment	Not Detected at Port of Entry	Moved to Suitable Habitat	Contact with Host Material	Cumulative Risk Rating
Angiosorus solani	High (3)	High (3)	High (3)	High (3)	High (3)	High (3)	High (18)
Rosellinia bunodes	High (3)	High (3)	High (3)	High (3)	High (3)	High (3)	High (18)

7. Conclusion—Pest Risk Potential and Pests Requiring Phytosanitary Measures

The summation of the values for the Consequences of Introduction and the Likelihood of Introduction yields Pest Risk Potential values (Table 7). This is an estimate of the unmitigated risks associated with this importation.

Table 7. Pest Risk Potential.

Pest	Consequences of Introduction	Likelihood of Introduction	Pest Risk Potential
Epicaerus cognatus	Medium (9)	High (17)	Medium (26)
Globodera pallida	High (15)	High (18)	High (33)
Globodera rostochiensis	High (14)	High (18)	High (32)
Nacobbus aberrans	High (15)	High (18)	High (33)
Ralstonia solanacearum race 3	High (15)	High (18)	High (33)
Angiosorus solani	Medium (12)	High (18)	High (30)
Rosellinia bunodes	High (15)	High (18)	High (33)

Pests with an unmitigated Pest Risk Potential value of "Low" do not require specific mitigative measures beyond normal port-of-entry inspection, whereas a value within the "Medium" range indicates that specific phytosanitary measures may be necessary. The PPQ Guidelines state that a "High" Pest Risk Potential means that specific phytosanitary measures are strongly recommended, and that port-of-entry inspection is not considered sufficient to provide phytosanitary security.

C. Risk Mitigation Options

1. Measures for Pest Risk Reduction

The appropriate level of protection for an importing country can be achieved through the requirement of a single phytosanitary measure, such as inspection or a treatment, or through the combination of a variety of phytosanitary measures. The combination of specific phytosanitary measures that provides overlapping or redundant safeguards is distinctly different from the use of a single mitigative measure such as fumigation. These combinations vary in complexity;

however, they all require the integration of different measures, at least two of which act independently, with a cumulative effect achieving the desired level of phytosanitary protection (i.e., a systems approach) (FAO, 2001c). Specific mitigations may be selected from a range of preharvest and postharvest options, and may include safeguarding measures. Measures may be added or the strength of measures increased to compensate for uncertainty. Quantification of the effectiveness of each component may not be practical, but the aim is to ensure that the overall effectiveness of the combined components reduce pest risk to an acceptable level.

A systems approach for potatoes from Mexico could combine a range of mitigative measures including: 1) Pest free areas or pest free places of production for certain quarantine pests; 2) shipments limited to commercial consignments of potatoes for consumption; 3) use by growers of certified seed potatoes ("clean" propagative material) for the crop; 4) programs (e.g., chemical, cultural) in place to control pests within the crop; 5) preclearance oversight by APHIS officials; 6) potatoes washed and treated with sprout inhibitor in accordance with label requirements; 7) consignments inspected and certified by Mexico SAGARPA to be free of key quarantine pests; 8) use of pest-resistant varieties; 9) potatoes traceable to State of origin, packing facility, and grower and field; 10) consignments subjected to sampling and inspection after arrival in the United States, including microscopic examination for nematodes and testing for key quarantine pests (e.g., brown rot, ring rot, viruses); and 11) limits on distribution (e.g., consignment destinations the first year limited to areas of the United States within 15 miles of the Mexican border).

2. Phytosanitary Measures

The following discussions describe possible measures with information about their efficacy and their application to the extent that such information was available:

1) **Pest-free area**: Requiring potatoes to be produced in a pest free area will remove, *ipso facto*, specific pests from the pathway. Pest free areas should be approved by APHIS to be in compliance with standards specified in FAO (1996b). This measure is highly effective where it is feasible to implement based on the pests and areas of concern.

2) **Potatoes for consumption only**: Limiting the importation of potatoes to commercial shipments for consumption has two mitigative effects. Requiring commercial grade potatoes ensures a certain level of quality and cleanliness which results from commercial handling. This is a significant measure for pests that affect quality or associated with contaminants (e.g., soil). Limiting the end use to "consumption only" helps to prevent potatoes from being diverted to other purposes where they are more likely to come into contact with host material (i.e., growing plants) or for pests to be able to escape and establish in the United States. This has limited effectiveness because it depends largely on voluntary compliance.

3) **Certified seed potato for crop production**: This measure is highly effective in mitigating pest risk because it ensures the absence of specific pests, particular pathogens, or a defined low prevalence of pests at planting. Certified seed potato production is based on a generational process, under official control, in which a small quantity of nucleus stock of a variety is increased to commercial quantities over a number of generations (Armstrong, 2003). During

each generation, there is rigorous inspection and testing of the material to ensure that it is pest-free. The main components of seed potato certification include: sampling and testing of production areas to ensure freedom from nematodes; approval of land and seed to be multiplied; inspection of crops for varietal purity and crop health; sampling and testing for presence of viruses; formal classification of seed crops; inspection of tuber samples; and sealing and labelling of certified seed. Potatoes to be imported from Mexico should be sourced from an officially recognized seed potato certification system.

4) **Chemical spray program**: Pre-harvest chemical sprays may be used to control pests within production fields. Minimal pesticide efficacy is anticipated when pests have already entered plant tissue since there generally is no curative activity if non-systemic pesticides are used. The chemicals must be used in a manner consistent with their labelling.

5) **Potatoes washed and treated with sprout inhibitor**: Washing mitigates the pest risks posed by soil contamination, and the application of a sprout inhibitor limits the use of potatoes for propagation. Depending on the particular compound used and the dosage applied, sprouting has been reported to be curtailed by about 30-100% (e.g., Thon, 1991; Afek *et al*., 2000). Sprout inhibitors also may be effective in controlling some potato pests (e.g., Shelton & Wyman, 1980). The effectiveness of sprout inhibition in mitigating risk is similar to that of measure 2 above.

6) **Phytosanitary certification inspections**: These inspections consist of sampling and testing potato tubers during the growing season and after harvesting. Production areas would be subject to periodic, unannounced inspections by certified inspectors from PPQ and the national plant protection organization of Mexico to ensure that they meet stipulated requirements for the issuance of a phytosanitary certificate that would be required for each consignment. This measure is helpful for detecting pests present in the field which may be more difficult to detect post-harvest (e.g., viruses), but it needs to be combined with other measures to ensure the absence or reduced prevalence of pests of concern.

7) **Pest resistant varieties**: The use of pest resistant varieties is a common and effective component of systems approaches for reducing pest risk (Follet & Vick, 2002). The use of resistant potato varieties, for example, was successful in the complete control of *Globodera rostochiensis* (Anosova & Safronova, 2001).

8) **Point-of-entry sampling and inspection**: Sampling of consignments at ports-of-entry in the United States would combine visual inspection with laboratory testing. Visual inspection is useful to verify that certain phytosanitary certification requirements have been met and the consignment is generally free of contaminants. The efficacy of this measure depends on the statistical level of sampling and the detect-ability of the pests or articles of concern (e.g., soil). Laboratory testing requires that a portion of each sample taken for inspection be subjected to laboratory analysis for the detection of pathogens and to determine the efficacy of sprout inhibition. This measure has a much higher degree of precision than visual inspection, but the efficacy of the measure will depend on the statistical level of sampling.

9) **Limited distribution**: Limiting the distribution of consignments (e.g., to a 15 mile-wide zone along the Mexican border) will help ensure that the potential introduction and establishment of

pests with broad environmental tolerances is restricted to an extremely limited part of the country, facilitating detection, surveillance and eradication efforts if necessary. This also serves to establish a buffer zone that separates any potato pests that may be introduced from Mexico from the more extensive potato producing areas in the United States, which tend to be in the northern part of the country (NASS, 2003).

3. Monitoring

1) **Pre-shipment programs**: Inspection, treatments, or other mitigative measures conducted in Mexico should be done under the direct supervision of qualified APHIS and SAGAR personnel and in accordance with specified phytosanitary procedures. Such programs require monitoring all aspects of the application of any required phytosanitary measures and also aim to identify shortcomings or opportunities for program modifications. Provision should be made for the formal recognition of approved areas/sites/producers as well as conditions for revoking approvals and/or refusing certification for export to the United States. Production areas are normally subject to periodic, unannounced inspections by certified inspectors from PPQ and the national plant protection organization of Mexico to ensure that they conform to requirements. Integrity checks to ensure conformance with program guidelines may be conducted as part of inspection at U.S. ports-of-entry.

2) **Shipments traceable to place of origin in Mexico**: A requirement that potatoes be packed in containers with identification labels indicating the specific place of origin is necessary to ensure traceability to each production site.

4. Conclusions

The number of pests that require mitigation, and the diverse nature of these pests make it unlikely that a single mitigative measure will be adequate to reduce the risk to acceptable levels. For this reason, a combination of measures in a systems approach is most feasible. The specific measures and the strength of measures to be used will depend on the combinations that are most feasible and the rigor to which they can be applied.

This document does not purport to establish specific workplans or to evaluate the quality of a specific program or systems approach. It identifies risks and provides information regarding known mitigative measures. The specific implementation of measures, as would be present in an operational workplan, is beyond the scope of this document.

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